

OrbView-3 Geometric Calibration and Geopositional Accuracy

JACIE
High Spatial Resolution Commercial Imagery
Workshop

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Presentation Outline

- OV-3 Specifications
- Geometric Calibration System
- OV-3 Geometric Calibration Events
- OV-3 Geometric Camera Calibration
- OV-3 Geolocation Accuracy Performance

OV-3 Specifications

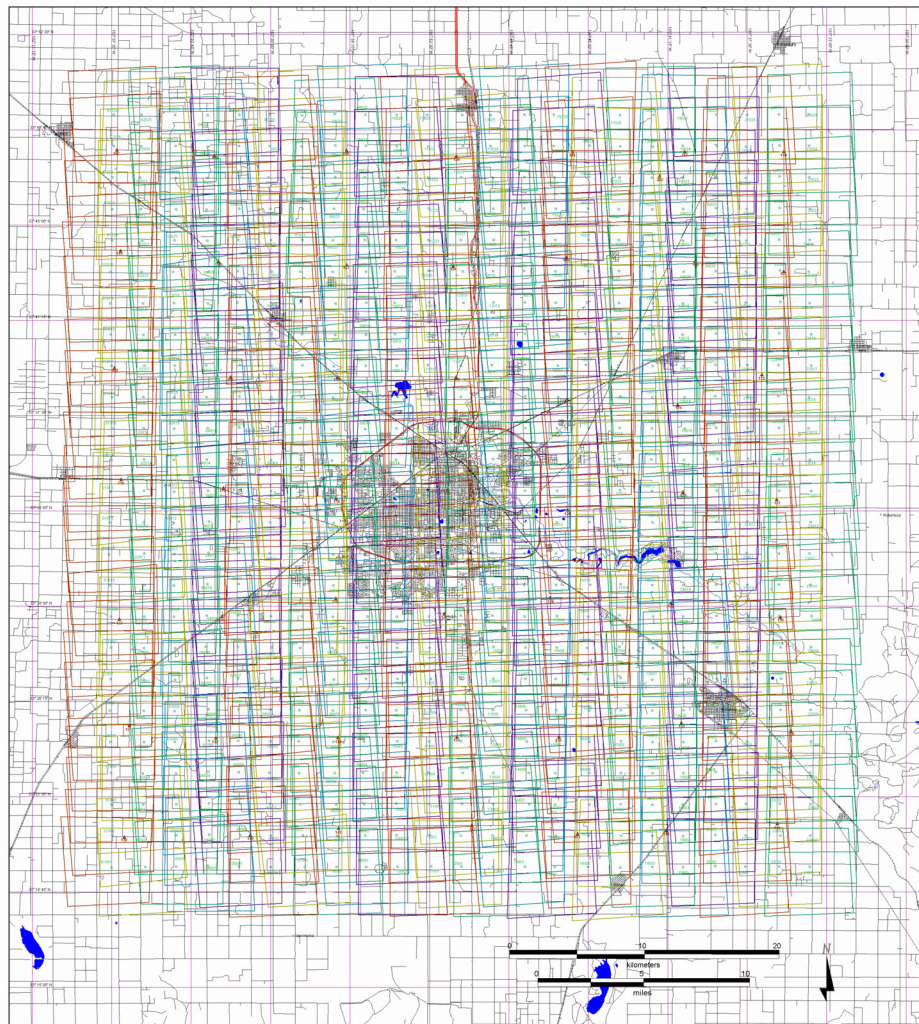
- Sun-synchronous orbit
 - 470 km
 - 10:30 am descending node crossing
- Ancillary sensors
 - Viceroy GPS receiver
 - Two Sordern star trackers
 - Fiber Optic Gyros
- Camera
 - 2.78 meter focal length
 - Panchromatic band has 8032 detectors at 6 microns, 1 meter GSD
 - Multispectral bands (4) have 2008 detectors each at 24 microns
- Image collection
 - North-South, East-West, West-East, and South-North
 - Other azimuths are also possible



Geometric Calibration System

- Geometric Calibration Range
 - Located in Lubbock, Texas
 - Consists of 575 aerial photographs
 - 1 : 25,000 scale, 40 cm GSD
 - 60% endlap and 60% sidelap (double block configuration)
 - Covers a 50km by 50km area
 - 48 ground survey points
 - Absolute accuracy < 1 meter (CE90/LE90)
 - Has produced thousands of control points
 - Using autocorrelation between aerial and satellite imagery

Geometric Calibration System (cont)



OrbView-3/4 Geometric Calibration Range

Geometric Calibration System (cont)

- Software
 - GIPSY-OASIS for orbit determination (by JPL)
 - Gravity model, drag model, stochastic force model, GPS receiver model
 - Alignment Kalman Filter for attitude determination system calibration
 - Stars form the absolute reference for calibration
 - Estimates alignment of star trackers and gyros, and gyro scale factors
 - MST (Multi-Sensor Triangulation) for geometric camera calibration
 - Object oriented design, framework, utilities, and Developer's Tool Kit
 - NORA Method to allow run-time selection of adjustment parameters
 - Numerical Partial Derivatives and Numerical Ground to Image Projection
 - Sensor Factory
 - Image Correlator / Control Point Generator
 - Autocorrelation between aerial and satellite imagery
- Hardware
 - Dual processor 3 GHz, 3GB memory, 1.5 TB storage, twin 20 inch displays
- Staff

Geometric Calibration Events

2003 June 26	OV-3 launched
2003 July 26	First image
2003 July 27	Initial calibration of the attitude determination system
2003 Aug 22	Coarse boresight adjustment
2003 Sep 05	Final camera focus adjustment
2003 Sep 17	Orbit determination model tuned and verified
2003 Sep 17	Coarse geometric calibration of the camera
2003 Oct 03	Refined calibration of the attitude determination system
2003 Nov 04	Initial geometric calibration of the camera

Initial Geometric Camera Calibration Summary

- Block Adjustment
 - 15 images
 - 13 panchromatic and 2 multispectral
 - 3,875 ground control points
 - 33,093 image rays were observed on the OV-3 images
 - Average 8.5 OV-3 image rays per ground control point
- A posteriori
 - Error estimate in focal length is 48 microns (1 sigma)
 - This equates to less than 0.1 pixel at the end of the array
 - Error estimates for roll and pitch camera alignments are 0.5 arcsec (1 sigma)

Ground Control Points and Footprint Plot for Initial Geometric Camera Calibration of OV-3

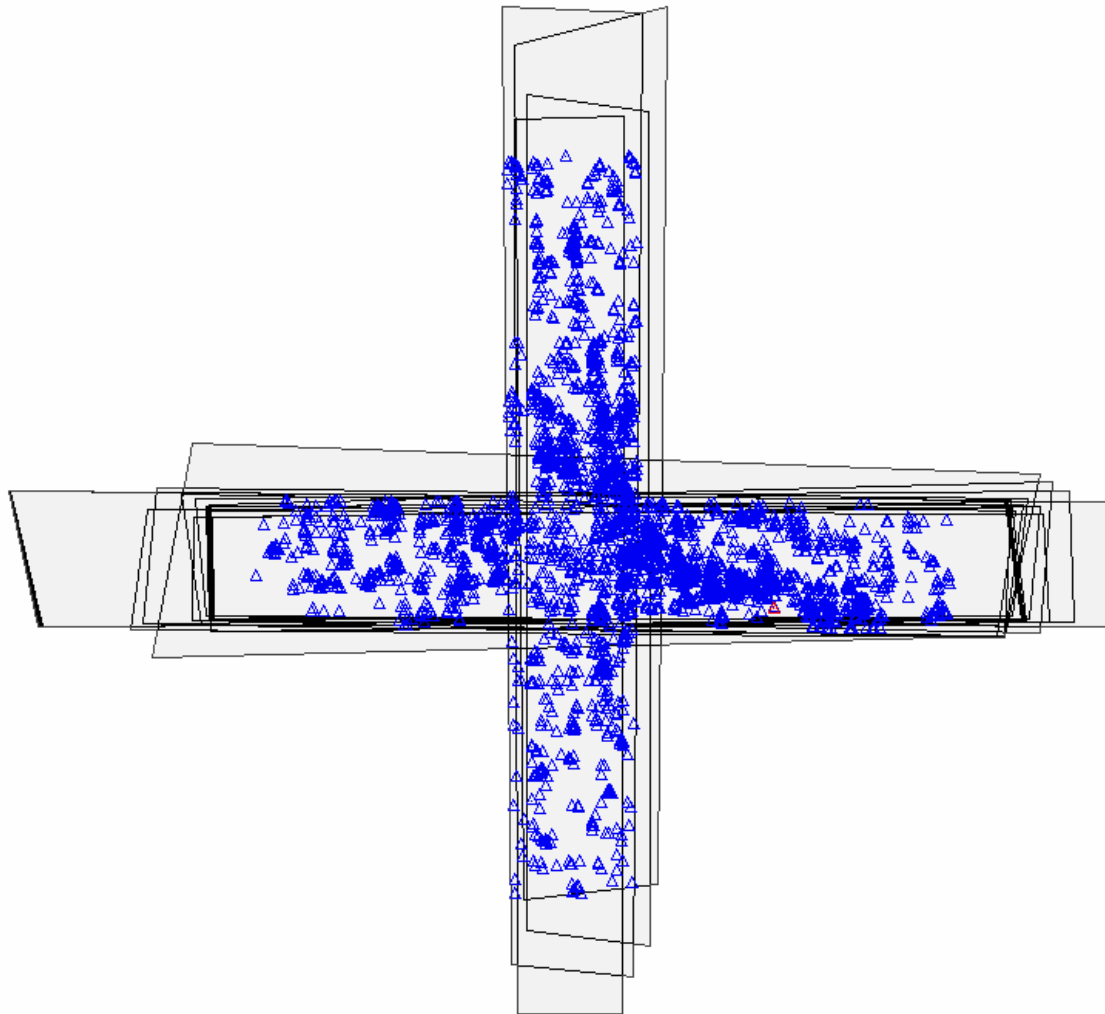
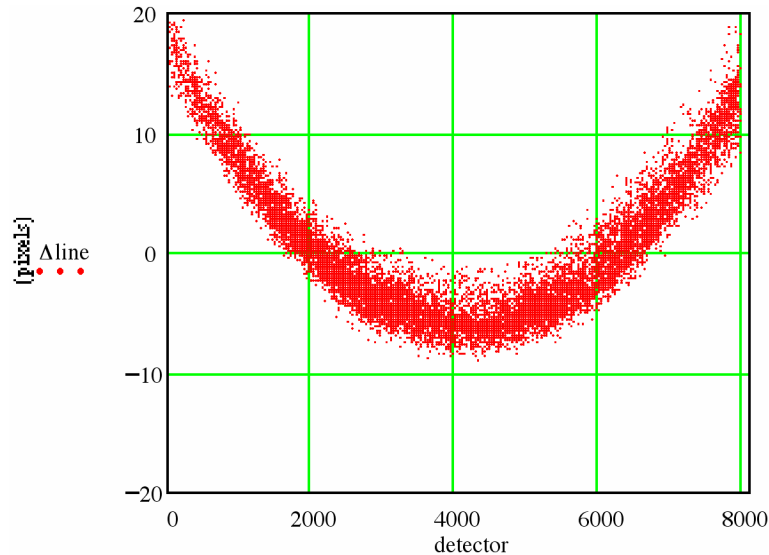
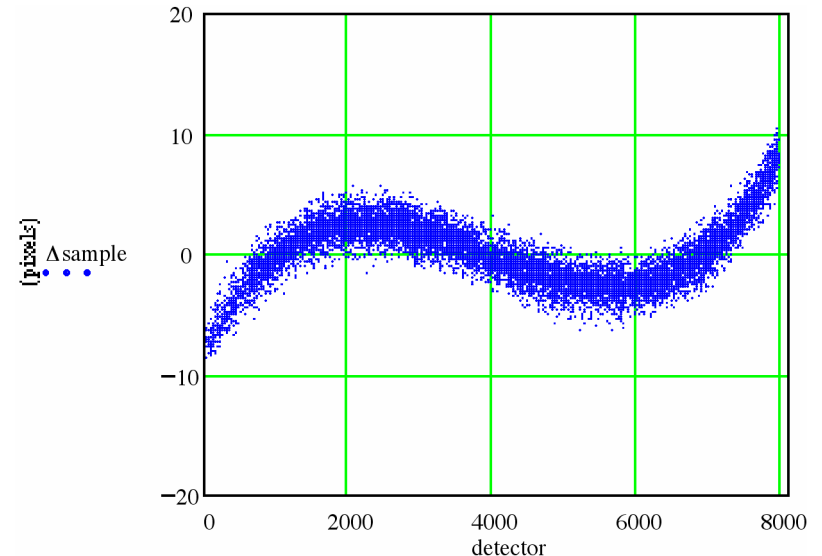


Image Residuals Before Camera Calibration

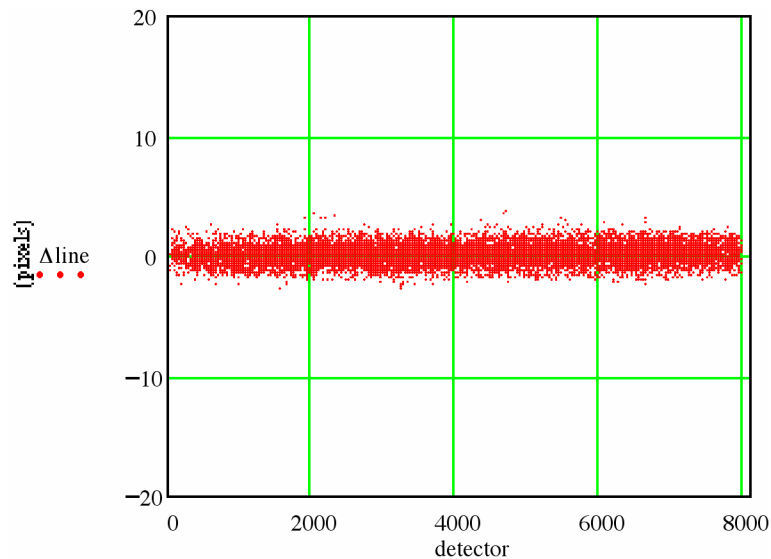


along scan direction

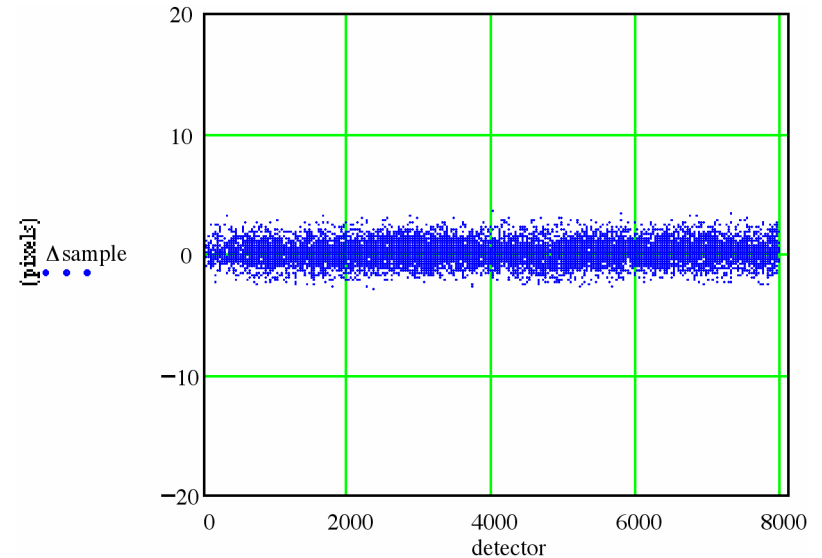


across scan direction

Image Residuals After Camera Calibration



along scan direction



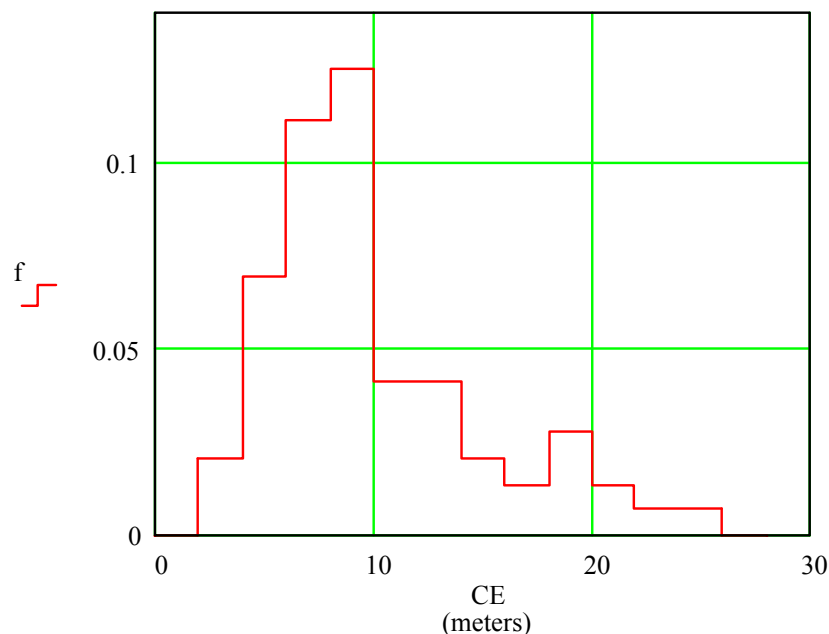
across scan direction

Geolocation Accuracy Evaluation Process

- Comparison to ground control points
 - Monodrops
 - Direct positioning without any triangulation adjustment
 - The photo ray is intersected with the elevation of the ground control point to produce the OV-3 latitude and longitude
 - Geographic Lat/Long differences are computed between the OV-3 and Ground Control Coordinates
 - Stereo measurement
 - OV-3 triangulation is performed using tie points
 - Space intersection is used to produce OV-3 coordinates of each control point location
 - Geographic Lat/Long/Height differences are computed between the OV-3 and Ground Control Coordinates

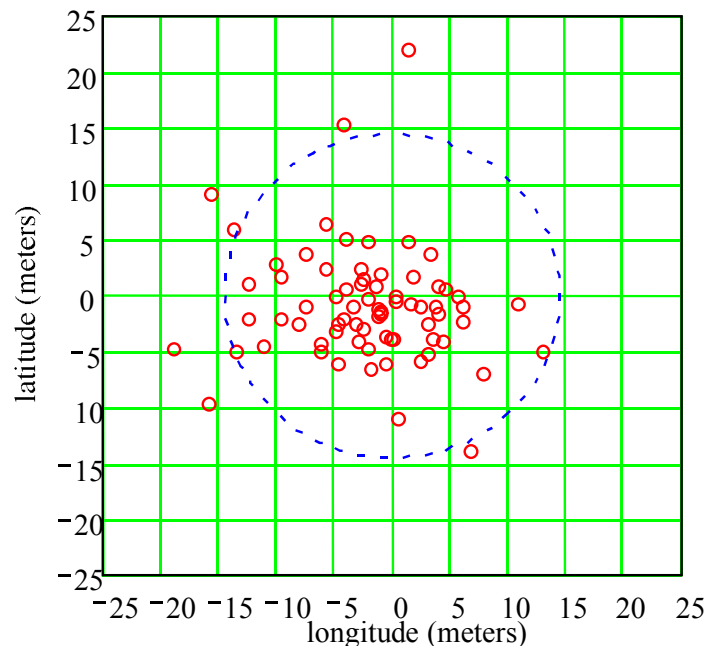
Observed Panchromatic Monodrop CE Histogram

- 72 images over 17 sites worldwide
 - median CE90 = 9 meters
 - mean CE90 = 10 meters
- **90th percentile CE90 = 18 meters**



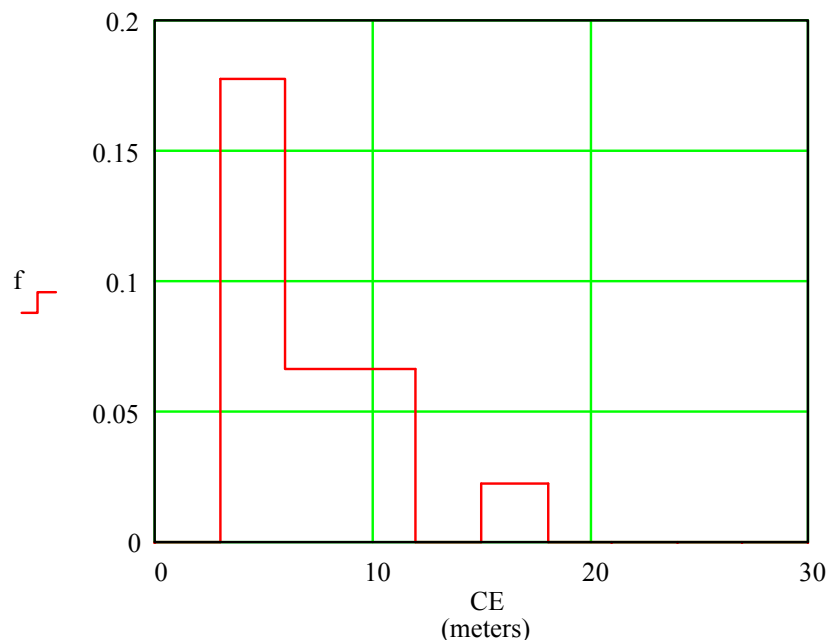
Observed Monodrop Random Bias

- 72 panchromatic images at 17 sites
 - mean = (-0.9m,-2.3m) (lat,lon)
 - standard deviation = (5.2m,6.2m) (lat,lon)
 - correlation between latitude and longitude = -0.1
- **CE90 of random bias = 14.5 meters**



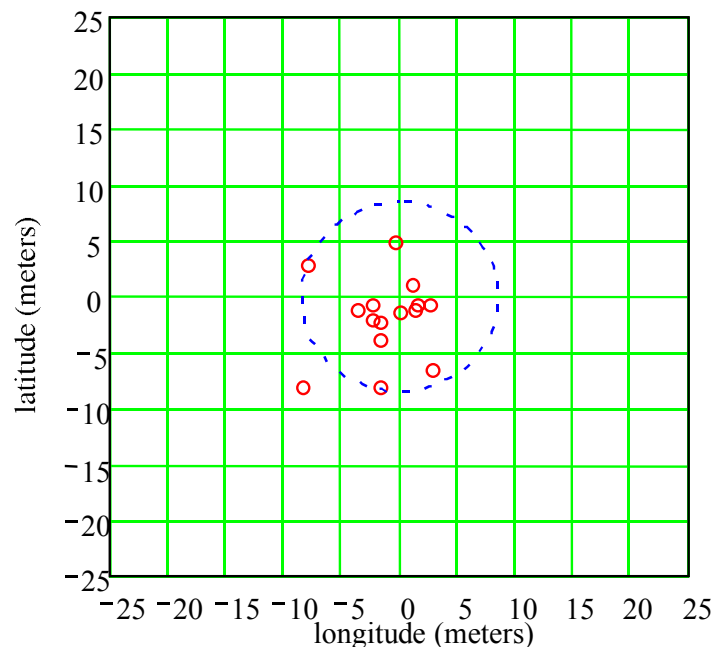
Observed Panchromatic Stereo Pair CE Histogram

- 15 stereo pairs
 - median CE = 6 meters
 - mean CE = 7 meters
- **90th percentile CE₉₀ = 11 meters**



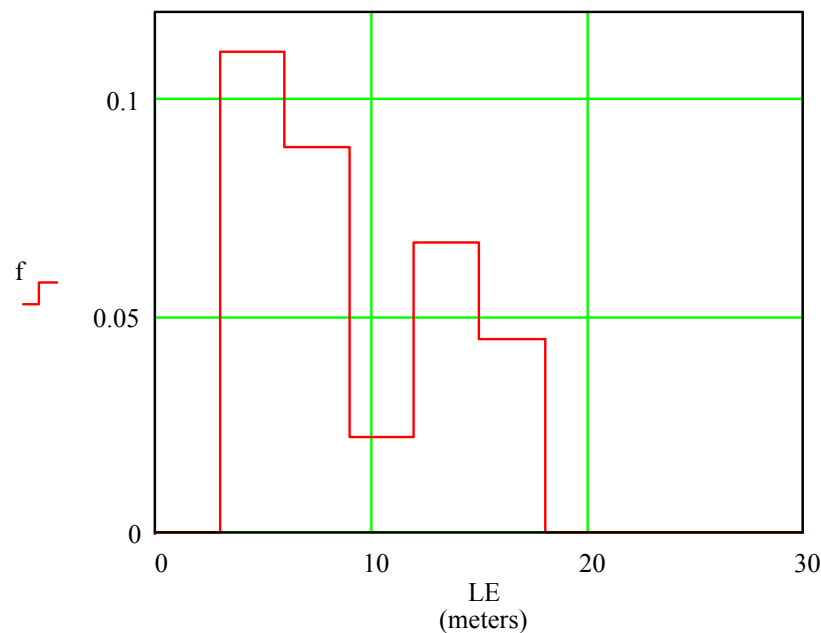
Observed Random Bias of Stereo Pairs

- 15 stereo pairs
 - mean = (-1.8m,-1.4m) (lat,lon)
 - standard deviation = (3.5m,3.2m) (lat,lon)
 - correlation between latitude and longitude = 0.1
- **CE90 of random bias = 9 meters**



Observed Linear Error of Stereo Pairs

- 15 stereo pairs
 - median LE90 = 8 meters
 - mean LE90 = 9 meters
- **90th percentile LE90 = 16 meters**



Summary

- OV-3 was launched on 2003 June 26
- Initial geometric calibration was completed on 2003 Nov 04
 - Orbit Determination
 - Alignment Kalman Filter
 - Camera
 - subpixel interior orientation, 0.5 arcsec alignment knowledge
- Geolocation accuracy performance
 - Monoscopic
 - 18 meters 90th percentile CE90
 - 14.5 meters random bias CE90
 - Stereoscopic
 - 11 meters 90th percentile CE90
 - 9 meters random bias CE90
 - 16 meters 90th percentile LE90

References

- Mulawa, D., *Preparations for the On-Orbit Geometric Calibration of the OrbView 3 and 4 Satellites*, ISPRS XIXth Congress Proceedings, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXIII, Part B1, Book 1, pp. 209-213, Amsterdam, 2000.
- Mulawa, D., *On-Orbit Geometric Calibration of the OrbView-3 High Resolution Imaging Satellite*, ISPRS XXth Congress Proceedings, Commission 1, paper 1, Istanbul, 2004.